7.15 MISSISSIPPI RIVER IMPACTS

The changes in the operating criteria making up each of the alternatives presented in this chapter provide different release patterns from Gavins Point Dam. Some of these differences are more pronounced than others. In some cases, they are dramatic enough to show up on the annual hydrograph for Hermann, Missouri, which is the last location modeled on the Missouri River. These flows join those from the Upper Mississippi River to make up the flow that passes St. Louis, Missouri. Because of these differences and the concerns regarding impacts on the Mississippi River, an analysis was conducted of potential impacts on the Mississippi River, including impacts to the endangered pallid sturgeon. Prior studies and analysis of annual hydrographs indicated that continued evaluation of Mississippi River water intakes, saltwater intrusion, and flood damage were not warranted. Impacts on these resource categories were determined to be indistinguishable. For the alternatives addressed in this chapter, Mississippi River resource evaluations were conducted for hydraulics and hydrology, side channel improvements, dredging, navigation, and channel improvement features.

Details on methods employed in these studies and previous evaluations are included in the Mississippi River Studies technical report (Corps, 1998l).

7.15.1 Hydraulic Impacts on the Mississippi River

This portion of the RDEIS discusses the results of the hydraulic analyses performed to determine the impact of the Missouri River Mainstem Reservoir System operating alternatives on the stages and flows on the Mississippi River. Discussions are limited to the CWCP, the MCP, and the four GP options: GP1528, GP2021, GP1521, and GP2028. The discussion is also limited to the gaging stations at St. Louis, Missouri, and Cairo, Illinois, which were used to evaluate the economic impact on the Mississippi River. A brief discussion on the Missouri River flow at Hermann, Missouri is also included.

Hermann, Missouri

The only variable that differentiated the numerical model runs on the Mississippi River for each alternative was the flow at Hermann. The differences in flow patterns at Hermann that occur among the alternatives should, therefore, be reflected at downstream gaging stations along the Mississippi River. Figure 7.15-1 shows the average monthly flow on the Missouri River at Hermann, Missouri for the CWCP, the MCP, and the four GP options. In comparing the MCP to the CWCP, the average monthly flows at Hermann are similar through September with differences of less than 1 kcfs. The MCP results in slightly higher flows than the CWCP in October, but substantially lower flows in November. This occurs because the Missouri River navigation season is curtailed earlier during low water years as part of the additional drought conservation features of the MCP. The GP1528 option, which has the least amount of deviation from the CWCP of the four GP options, has a slight increase in average monthly flows at Hermann during the months of May and June, and a moderate reduction of monthly flows in July and August. Flows in September and October are slightly higher than the CWCP, but average slightly lower again in November as the additional conservation measures take effect in drought years. The other GP option with a 15-kcfs spring rise, GP1521, has a similar affect in May and June, but considerably lower flows than the GP1528 option during July and August as a result of the 25/21-kcfs summer low flows from Gavins Point Dam. The GP2028 and GP2021 options have higher flows in May and June than the other two GP options, due to their higher spring rise out of Gavins Point Dam, and July and August flows similar to the GP1528 and GP1521 options, respectively. The options with the lowest summer flows, GP1521 and GP2021, have the highest flows during the fall as excess flood evacuation is moved into the fall. The GP2028 option has fall flows similar to the GP1528 option. Mean monthly stages at Mississippi River gaging stations for the MCP and the four GP options should reveal similar patterns of increase or decrease in mean monthly stages when compared to the CWCP.

St. Louis, Missouri

Figure 7.15-2 shows the computed mean stage for each month at St. Louis for the CWCP, the MCP, and the four GP options. The pattern of flow change at Hermann is replicated here, as expected. The MCP is very similar to the CWCP except for having lower stages in November due to the drought conservation measures. The spring rise of the GP options becomes virtually indistinguishable at the St. Louis gage, making only about 0.1 foot of difference in May and June. The GP options with the minimum service summer low flows, GP1528 and GP2028, have nearly identical results at the St. Louis gage. Both result in a 0.4-foot decrease in mean monthly stage compared to the CWCP and the MCP during August and have slightly higher fall stages than the MCP. The GP1521 and GP2021 options result in a 1.0-foot decline in St. Louis stage in August when compared to the CWCP and the MCP. Fall stages for these options are considerably higher than both the CWCP and the MCP.

Figures 7.15-1 and 7.15-2 provide a glimpse of how the alternatives compare to the CWCP and with each other, but the impact of the alternatives on flooding, which begins at 30 feet on the St. Louis gage, and to navigation, which begins when the St. Louis gage falls below 2.0 feet, must be analyzed on an event-by-event basis using the daily stage hydrographs.

Figure 7.15-3 shows the maximum stage, in feet above the 30-foot flood stage, attained at St. Louis during each year under each alternative. By focusing on the feet above flood stage, critical periods for increased flood risk are identified. The greatest increase in the annual maximum stage during flooding conditions occurred during 1965. The MCP was 0.4 foot higher than the CWCP. The GP1528 and GP2028 options added an additional 0.2 foot to the MCP, and GP2021 and GP1521 were 0.5 foot higher than the MCP, or 0.9 foot higher than the CWCP. Other events that had a notable increase in the St. Louis peak stage include 1975, which had a 0.7-foot increase over the CWCP for the GP1521 option; 1986, which had a 0.6- to 0.8-foot increase with the four GP options; and 1995, which had a 0.3- to 0.7-foot increase with the GP options. The greatest decrease in the annual maximum stage while in flood was 0.4 foot, which occurred in 1992 under the MCP and the GP1528 and GP2028 options.

Figure 7.15-4 shows the minimum stage at St. Louis during each year for each alternative. The stage at which navigation on the Middle Mississippi River begins to be impacted is 2.0 feet. Under the CWCP, stages below 2.0 feet occur in all but 11 years out of the 66 years modeled (1930 to 1995). The 11 years in which the stage does not fall below 2.0 feet all occur between 1973 and 1995. In the 13 years between 1983 and 1995, there are only four years in which the stage falls below 2.0 feet. As shown in Figure 7.15-4, the greatest decrease in the annual minimum stage is 1.4 feet, which occurs in 1941 under the MCP. The minimum stage under all of the GP options is 0.3 foot higher than the MCP in 1941. In general, during the most severe low-flow periods when stages fall below -2 feet at St. Louis, none of the alternatives result in a stage that is more than 0.7 foot lower than the CWCP. The greatest increase in the annual minimum stage modeled was 0.7 foot in 1949 under the GP2021 and GP1521 options.

Figure 7.15-5 shows the annual stage duration curves at St. Louis for the CWCP, the MCP, and the four GP options. The duration curves show the percent of the time a given stage is equaled or exceeded. For example, under the CWCP, the stage of 2.0 feet (the stage at which navigation impacts begin) is exceeded about 77 percent of the time, meaning the river remains below 2.0 feet about 23 percent (100-77) of the time. An increase in the exceedance duration figure means that the river spends more time above that stage and less time below that stage, and conversely, a decrease in the exceedance duration figure means that the river spends less time above that stage and more time below that stage. Figure 7.15-5 shows virtually no difference in the stage duration at St. Louis for the CWCP, the MCP, and the four GP options. The greatest change in the annual exceedance duration at any given stage is a decrease of 0.87 percent at a stage of -1.0 foot under the MCP, compared to the CWCP. The 0.87 percent is equivalent to 3.2 days per year. The GP options also have their greatest effect on the low end of the duration curve with maximum decreases of less than one percent at a stage of 0.0 to 1.0 foot at St. Louis.

Figures 7.15-6 through 7.15-17 show stage exceedance duration curves for each month of the year. Although the annual duration curves (Figure 7.15-5) show no significant variation between the CWCP, the MCP, and the four GP options, monthly duration curves reveal significant differences during certain months. There is very little difference among the monthly flow duration curves for January through May; the maximum variation is generally much less than 1 percent. In June there is very little difference between the CWCP and the MCP, but the exceedance durations for the GP options are generally 1 to 1.5 percent higher than the CWCP as a result of the Gavins Point Dam spring rise having worked its way down to the St. Louis area. The greatest increases in exceedance durations during June are limited to stages in the 10-to-15 feet range, which has little impact on either flood control or navigation. Significant decreases in exceedance duration at lower stages occur during July and August under the GP2021 and GP1521 options, including a 9 percent decrease in exceedance duration at the 2.0-foot stage for both options. The MCP is very similar to the CWCP during July and August. The GP1528 and GP2028 options have a 1 to 2 percent reduction in exceedance frequency during July, and 2 to 3 percent reduction during August, for St. Louis stages in the range of 1 to 11 feet. All of the alternatives show moderate increases in exceedance duration at lower stages in October as a result of floodwater being evacuated from the mainstem lakes during the fall. Significant decreases in exceedance duration occur at low stages in November under the MCP and GP1528 and GP2028 options, including a 10.5 percent decrease at 0.0 feet stage under the MCP. The GP1521 and GP2021 options have a slight increase in the exceedance frequency at all stages below 25 feet during November.

Cairo, Illinois

Unlike the Middle Mississippi River, which typically crests in April or May and reaches the lowest levels in December and January, the Lower Mississippi River at Cairo, Illinois, typically crests in March or April and reaches its lowest levels in September or October. By December or January, the Cairo gage is usually on a rise. A change in the Missouri River flow, therefore, impacts the Lower Mississippi River somewhat differently than it does the Middle Mississippi River, particularly during the low-flow periods.

Figure 7.15-18 shows the computed mean stage for each month at Cairo for the CWCP, the MCP, and the four GP options. The pattern of flow change at Hermann is replicated as it was at St. Louis, although the impact on the stage at Cairo is a fraction of the St. Louis impact because of attenuation, the introduction of the Ohio River flow, and the fact that the river is much larger at Cairo than at St. Louis. All of the mean monthly stages for the MCP and the GP options are within 0.2 foot of the stages modeled for the CWCP.

Figure 7.15-19 shows the annual maximum stage in feet above the 40-foot flood stage, attained at Cairo under each alternative. The greatest increase from the CWCP in the annual maximum stage that occurred during the time the river was in flood was 0.6 feet under GP2021 in 1987. The greatest decrease from the CWCP in the annual maximum stage while in flood was 0.6 feet, which occurred under GP1528, GP2021, and GP1521 in 1938.

Figure 5.15-20 shows the minimum stage attained at Cairo each year under each alternative. The stage at which the navigation on the Lower Mississippi River begins to be impacted is 11.8 feet, which, under the CWCP, occurs in about 60 percent of the 61-year (1935 to 1995) study period. The greatest decrease in the annual minimum stage was 1.8 feet, which occurred in 1970 under the GP1528, GP2021, and GP1521 options; however, the reduction occurred when the stage was well above the 11.8-foot triggering stage for navigation impact. The greatest decrease in the annual minimum stage while the river was below the 11.8-foot triggering stage was 1.5 feet, which occurred in 1936 under the MCP and the GP2028 option. Higher releases from Gavins Point Dam provided during the month of October for the MCP and the GP options increase the minimum stage at Cairo many years in the study period. The greatest increase in the annual minimum stage was 2.8 feet in 1938 under the MCP and the GP2028 option, and in 1952 under the GP2021 option.

Figure 7.15-21 shows the annual stage duration curve at Cairo for the CWCP, the MCP, and the four GP options. The duration figures are given in percent of the time a given stage is equaled or exceeded. The figure demonstrates that there is no appreciable difference between the annual stage duration curves for the CWCP and other alternatives at the Cairo gage on the Mississippi River. Monthly stage duration curves, though not presented, would likely show differences between the alternatives similar to those seen at St. Louis, but on a smaller scale.

7.15.2 Side Channel Impacts

Description of Effort and Methods

The St. Louis District collected bathymetry (channel elevation data) during spring high water of 2001 on ten side channels of the Middle Mississippi River (MMR) between St. Louis, Missouri (RM 180) and Cairo, Illinois (RM 0). The side channels and acreage of coverage are listed here in order of river mile: JB Chute, RM 167, 40.47 acres; Atwood Chute, RM 161, 15.91 acres; Calico Chute, RM 148, 26.31 acres; Osborne Chute, RM 145.5, 113.51 acres; Moro Chute, RM 125.5, 234.34 acres; Kasky Chute, RM 117, 133.67 acres; Cottonwood Chute, RM 78.5, 268.78 acres; Schenimann Chute, RM 60, 202.05 acres; Marquette Chute, RM 49.5, 431.6 acres; and Santa Fe Chute, RM 38, 523.57

acres. The bathymetry data for the chutes were collected using the high-resolution multi-beam echo sounding method, which collects highly accurate data and provides full bank-to-bank coverage. These data were thinned and then analyzed using a geographic information system (GIS). River stages modeled for each of the plans were plotted using the bathymetry coverage in order to compare losses and gains of total wetted area and the loss of connectivity of side channels to the main channel. Comparisons were made between the CWCP, the MCP, and the two GP options that cover the range of flow options: GP1528 and GP2021.

Focus of Impact Analysis

An impact analysis that compared the CWCP, the MCP, and the GP1528 and GP2021 options was completed. While there may be increased stages experienced on the Mississippi River as a result of higher release rates from Gavins Point Dam during the spring, they were considered inconsequential to aquatic habitats. Analysis was limited to summer and fall seasons because relatively small changes in the hydrograph during this timeframe could result in major impacts to the available aquatic habitat found in the Middle Mississippi River.

Side channels were used to examine impacts because they provide important off-channel habitat for a myriad of species. Side channels are considered important habitat to the endangered pallid sturgeon (for habitat diversity, rearing areas for larval fish, and forage production). The quality of a side channel (water quality, habitat suitability, accessibility, etc.) relies heavily on the channel's connectivity to the main channel. Low dissolved oxygen levels under existing flow regimes in the Middle Mississippi River side channels are currently a concern. Many of the side channels or chutes have been partially or completely blocked to divert flow to the main channel to maintain navigation traffic. Once isolated or partially isolated, the side channels begin to resemble eutrophic lakes with water stratification and fluctuations in dissolved oxygen levels from top to bottom. As the side channels stratify they experience anoxic conditions at the substrate level, killing most of the invertebrate fauna. These low oxygen conditions have been documented in many of the Middle Mississippi River side channels (personal communication, B. Hrabik, Missouri Department of Conservation, Long-term Resource Monitoring Program, Open River Field Station, 2001). One of the goals of the Middle Mississippi River side channel plan is to maintain flow and increase connectivity in the side channels.

Changes in Middle Mississippi River stages, resulting from Missouri River flow changes, have the potential to affect water quality in side channels. Increased flows, especially during the warmer summer months, result in the inflow of water with higher dissolved oxygen levels. Shallow standing water also tends to be much warmer and an increased inflow of riverine water reduce temperatures. Inflows into deeper areas would disrupt stratification common in lake-like habitats. Increased flows during normally low-flow warm seasons benefit the aquatic fauna of the side channels. Reduced flows into side channels during this same period would have an adverse effect on aquatic fauna due to decreased dissolved oxygen conditions and warmer water.

Natural resource agencies have suggested that suitable winter habitats may be scarce in the Middle Mississippi River and may limit some fish populations. During the winter, side channels are generally warmer and have slower current velocities than other riverine habitats. They provide over-wintering fish habitat for many species. Fish actively seek out and move into the side channels in the fall and over the winter (Bodensteiner and Lewis, 1992). Once in these protected areas, fish actively seek out specific microhabitats. For example, bluegills and black crappies actively avoid areas with water temperature less than 1^{o}C and current velocities greater than 1 centimeter per second (cm/s) (Knights et al., 1995).

Changes in Middle Mississippi River stages resulting from Missouri River flow changes have the potential to affect the ability of fish to enter or exit side channels. Connectivity to the main channel is important throughout the year. During the summer months, connectivity is important for overall production in the Mississippi River (e.g., macroinvertebrate production, rearing areas for young fish, etc.). During the fall months, side channels are critical to those species seeking over-wintering habitat.

Impacts on Wetted Area

Loss of aquatic area was an important factor in the analysis. Table 7.15-1 shows the losses and gains of aquatic areas in each chute for the CWCP, the MCP, and the four GP options for average river

Table 7.15-1. Wetted acreage lost or gained by alternatives.

	Wetted Acres Lost or Gained Compared to the CWCP					
	Based On Monthly Mean Stage			Based on Monthly Mean Low Stage		
	MCP	GP1528	GP2021	MCP	GP1528	GP2021
JB Chute						
August	0.00	-0.46	-1.27	0.00	-2.44	-4.54
September	0.09	0.00	0.00	0.43	-0.39	-1.15
October	0.24	0.34	0.42	1.21	1.60	-1.58
November	-0.56	-0.33	0.14	-2.86	-2.01	0.77
Atwood						
August	0.00	-0.24	-0.59	0.00	-0.51	-1.14
September	0.07	0.00	0.00	0.08	-0.10	-0.31
October	0.12	0.18	0.24	0.22	0.29	-0.40
November	-0.34	-0.21	0.16	-0.52	-0.36	0.13
Calico						
August	0.00	-1.22	-3.03	0.00	-1.35	-2.70
September	0.28	0.00	0.00	0.22	-0.22	-0.66
October	0.59	0.89	1.19	0.70	0.96	-0.87
November	-1.76	-1.17	0.94	-1.65	-1.19	0.49
Osborne						
August	0.00	-3.47	-9.88	0.00	-6.77	-13.23
September	0.80	0.00	0.00	0.96	-1.08	-3.17
October	1.73	2.51	3.34	3.68	4.96	-4.13
November	-4.81	-3.08	2.88	-8.79	-6.74	2.65
Moro						
August	0.00	-3.65	-7.88	0.00	-2.28	-4.02
September	0.69	0.00	0.00	0.31	-0.56	-1.12
October	2.10	2.10	3.62	1.44	1.66	2.42
November	-5.15	-3.05	3.11	-2.42	-1.82	-1.25
Kasky						
August	0.00	-4.44	-9.12	0.00	-3.40	-5.74
September	0.87	0.00	0.00	0.43	-0.88	-1.64
October	2.58	2.58	4.37	1.97	2.52	3.70
November	-6.24	-3.67	3.85	-3.70	-2.73	1.72
Cottonwood						
August	0.00	-5.13	-5.13	0.00	-14.08	-14.08
September	0.00	-0.55	-0.55	1.10	-3.55	-4.75
October	1.02	2.47	1.97	3.60	7.16	7.16
November	-2.95	2.13	2.13	-7.16	4.27	4.27
Schenimann						
August	0.00	-7.63	-7.63	0.00	-9.15	-9.15
September	0.00	-0.75	-0.75	0.76	-2.18	-3.10
October	1.50	3.66	2.80	2.16	4.50	4.50
November	-4.29	3.79	3.79	-4.50	2.87	2.87
Marquette						
August	0.00	-20.96	-20.96	0.00	-22.22	-22.22
September	0.00	-2.08	-2.08	1.95	-5.61	-7.28
October	4.18	10.51	8.41	5.86	12.26	12.26
November	-12.50	9.39	9.39	-12.26	8.32	8.32
Santa Fe						
August	0.00	-10.32	-25.93	1.64	-8.30	-17.74
September	0.00	5.27	-2.59	1.82	-1.65	-4.72
October	5.27	10.43	12.95	5.08	6.72	8.32
November	-12.71	-7.55	9.21	-8.32	-4.84	6.75

stages during late summer and fall months, as well as average low water stages for those same months. Water elevations in the chutes were assumed to rise and fall with the river whether there was a direct connection or not due to groundwater influences.

The analysis also considered the water in a disconnected chute as part of the aquatic habitat of the system, i.e., aquatic area is not discounted because it is inaccessible to fish. For the month of August, the table clearly shows that there is an increasing loss of aquatic area for the GP1528 and GP2021 options, respectively, with relatively minute impacts from the MCP. Progressing from summer to fall, the impacts of the GP1528 and GP2021 options gradually invert, proving additional wetted acreage during this time, while wetted areas decrease under the MCP. This indicates that while there may be negative impacts to fish access and water quality within chutes during the summertime, there may be benefits to fish off-channel over wintering areas, depending upon the alternative.

Chutes Showing Greatest Changes

While there is definitely loss of aquatic acreage within chutes in the summertime, the suitability of the available aquatic habitat or the accessibility of the off-channel areas may be limiting. Many chutes are already limited under the CWCP because of sedimentation or other natural or man-made factors. The chutes that will be negatively or positively affected by the alternatives under consideration are discussed below.

Access to off-channel areas is currently a problem with many chutes of the Middle Mississippi River and, because of that, it is important that chutes that are connected retain that condition. Jefferson Barracks Chute under average low river stages in August currently maintains some degree of flow-through. Under the GP1528 option, and more drastically so under the GP2021 option, this condition will not be retained in August, and it is possible that water quality within the deeper portions of the side channel may degrade. This condition is shown in Figure 7.15-22. Atwood Chute does not loose its flow-through characteristics during average low summer flows, but would loose some of its aquatic area due to decreased stages in the summer. Calico Chute does not maintain flow through the summer months, and currently there is no connectivity to the main channel during August mean low stage. However, the chute does have a connection to its lower end during mean August stage under the CWCP. Under the GP1528 and GP2021 options, the connection to the lower scour hole is lost (Figure 7.15-23). Osborne Chute and Schenimann Chute show similar impacts as those in Calico Chute from the same alternatives during mean river stages in August and September. At Kasky Chute, under average summer stages under the CWCP, the southernmost island is surrounded by water. Under the GP1528 and GP2021 options, this shallow water habitat is not available, and under the GP2021 option, island tip habitat has been lost (Figure 7.15-24). In the Middle Mississippi River, pallid sturgeons have been shown to select downstream island tips (Sheehan et al., 2000).

Under GP1528 and GP2021, access is enhanced at the lower end of Schenimann in October, which may enhance fish passage into the area as they move into wintering areas; however, the access to this end of the chute is available under all plans by November.

Discussion of Worst-case Scenario

A worst-case scenario, or the case where the CWCP remains at or above low mean water during August, but the MCP or the GP1528 or GP2021 options fall well below (up to 4 feet lower), was analyzed. The flows during 1971 were chosen to show these effects. Table 7.15-2 shows the loss of acreage at each side channel under this scenario. The MCP does not show any differences from the CWCP, and so is not shown in the chart. This scenario shows that, while on average the impacts of the alternatives on summer flows can be relatively insignificant, there can be a great loss of aquatic area during certain annual hydrographs in comparison to the CWCP. It also shows that during those same hydrographs, there may be a significant increase in available aquatic habitat in the wintertime.

7.15.3 Dredging

The alternative flow plans potentially could impact the Mississippi River dredging requirements. In order to evaluate this potential impact, the hydrographs for each plan were compared against the CWCP. In the interest of time, only low water years were evaluated. During a cursory overview, significant impacts were more definable during the low water years of 1937, 1940, 1963, 1964, 1888, and 1989. The following characteristics of the alternatives were evaluated:

Table 7.15-2. Loss of wetted area by plan in August and November 1971.

Chute	Month	Plan	Acres	Chute	Month	Plan	Acres
Atwood	August	GP1528	-1.885	Marquette	August	GP1528	-52.640
Atwood	August	GP2021	-2.502	Marquette	August	GP2021	-59.537
Atwood	November	GP1528	0.367	Marquette	November	GP1528	32.796
Atwood	November	GP2021	0.170	Marquette	November	GP2021	53.017
Browns bar	August	GP1528	-21.073	Moro	August	GP1528	-13.702
Browns bar	August	GP2021	-29.129	Moro	August	GP2021	-19.089
Browns bar	November	GP1528	44.995	Moro	November	GP1528	22.334
Browns bar	November	GP2021	65.434	Moro	November	GP2021	41.320
Calico	August	GP1528	-4.600	Osborne	August	GP1528	-21.087
Calico	August	GP2021	-5.598	Osborne	August	GP2021	-24.012
Calico	November	GP1528	3.538	Osborne	November	GP1528	12.977
Calico	November	GP2021	4.999	Osborne	November	GP2021	16.513
Cottonwood	August	GP1528	-61.577	Santa Fe	August	GP1528	-56.300
Cottonwood	August	GP2021	-76.153	Santa Fe	August	GP2021	-64.838
Cottonwood	November	GP1528	14.537	Santa Fe	November	GP1528	71.848
Cottonwood	November	GP2021	20.273	Santa Fe	November	GP2021	111.231
JB	August	GP1528	-7.479	Schenimann	August	GP1528	-24.757
JB	August	GP2021	-9.191	Schenimann	August	GP2021	-30.826
JB	November	GP1528	0.409	Schenimann	November	GP1528	12.629
JB	November	GP2021	0.510	Schenimann	November	GP2021	19.050
Kasky	August	GP1528	-11.292				
Kasky	August	GP2021	-14.629				
Kasky	November	GP1528	10.197				
Kasky	November	GP2021	20.198				

1. Does the hydrograph associated with the alternative have an earlier summer falling trend?
2. Does the alternative reach a St. Louis gage of zero at a significantly earlier date than the CWCP?
3. What effect does the alternative have on the minimum St. Louis gage reading?
4. What is the effect of the alternative on dredging quantities?

The alternatives did not produce a progressive summer falling trend when compared to the CWCP; therefore, the alternatives theoretically should not require an earlier dredging start. All flow plans drop the St. Louis gage to zero earlier than the CWCP during the representative low water years. The alternatives reach a St. Louis gage of zero earlier and, therefore, have negative impacts on channel maintenance activities and navigation interests compared with the CWCP.

The low water reference plane (LWRP) computations presented under Mississippi River Channel Improvement Features (Section 7.15.5) demonstrate a lower LWRP for the alternatives presented in this chapter and, therefore, indicate the need for additional dredging. A 0.4-foot drop in the LWRP (from a stage of -3.5 to -3.9 feet) will increase channel maintenance dredging quantities. An estimated 10 percent increase in quantities could result because of the additional dredging depth. An additional increase in quantity would also result from the additional amount of channel length dredged. Furthermore, a lower LWRP may increase the need to dredge channel crossings that have a low frequency of dredging. However, these last two factors are more difficult to quantify and would vary from site to site. Sufficient information is unavailable to quantify these aspects. The Corps' St. Louis District averages 5 million cubic yards annually on the reach from St. Louis to Cairo. An additional 10 percent equates to an additional 500,000 cubic yards, or a cost of $500,000 annually for the modified Missouri River flows. Environmental impacts associated with this additional dredging have not been evaluated.

7.15.4 Navigation

A primary concern regarding changes in a Water Control Plan for the Missouri River Mainstem Reservoir System is the potential effect on Mississippi River navigation. Reduced Missouri River flows increase the probability of low-water navigation conditions in the Mississippi River system south of Lock and Dam 27 upstream from St. Louis and where the Missouri River enters the Mississippi River. With low water, maximum tow size and draft are restricted below efficient levels at various locations on the Middle and Lower Mississippi River. Conversely, increased flows from the Missouri River decrease the probability of low-water navigation restrictions and decrease the total transportation costs of using these river reaches.

A navigation economic analysis was conducted to estimate the implications for navigation on the Mississippi River system considering the different potential Water Control Plans for the Mainstem Reservoir System. This analysis was broken down by reaches on the Middle Mississippi River (from St. Louis to Cairo, Illinois) and on the Lower Mississippi River (from Cairo to the Mouth of Passes, Louisiana).

Increased navigation costs begin on the Middle Mississippi River when the stage at St. Louis drops to 2.0 feet, which translates to a discharge of 90 kcfs or less. Various changes in tow size and draft must occur to continue to navigate between 2.0 feet and -4.5 feet (44 kcfs), when navigation must be suspended. Similarly, there are no restrictions on the Lower Mississippi River when the gage reading at Cairo is above 11.8 feet (189 kcfs). Tow size and draft restrictions are required between 11.8 feet and 3.5 feet (80.5 kcfs) at the gage, and navigation is suspended below 3.5 feet at Cairo.

Table 7.15-3 presents the average annual Mississippi River lost navigation efficiency costs. The total average navigation cost resulting from lost efficiency due to low flows on the Mississippi River for the CWCP is $45.27 million. All of the alternatives provide net improvements in Mississippi River navigation efficiency. Every alternative reduces flow and, therefore, stages on the Mississippi River during the summer months. These reduced stages result in more restricted navigation conditions during the summer. However, the additional flows in the fall months are coincident with extreme low stages on the Mississippi River and provided sufficient savings to offset the summer losses.

7.15.5 Mississippi River Channel Improvement Features, Mouth of Missouri River to Gulf of Mexico

The low water reference plane (LWRP) on the Mississippi River is used to establish crown elevation for dikes and other river engineering works. It is also used by navigation interests to obtain a general idea of the depth of water available at critical locations on the river. The LWRP profile along the Mississippi River is developed from LWRP stages computed at individual gaging stations based on the 97 percent exceedance flow for a specified period of record (typically from 1954 to the time of computation) being applied to a series of rating curves from a more recent period (typically the past 10 years). The LWRP was most recently re-computed in 1992 using the 1954 to 1991 period of record flows and 1982 to 1991 rating curves. Current LWPR stages for the Mississippi River downstream of St. Louis are shown in Table 7.15-4.

Table 7.15-3. Mississippi River lost navigation efficiency average annual costs ($millions).

Missouri River Scenario	Cairo	St. Louis	Both Reaches	Difference From Scenario CWCP
CWCP	18.77	26.50	45.27	0
MCP	17.98	26.04	44.01	(1.26)
GP1528	15.59	23.56	39.15	(6.12)
GP2021	14.97	23.01	37.98	(7.29)
GP1521	14.94	22.95	37.88	(7.39)
GP2028	15.62	23.61	39.22	(6.05)

Table 7.15-4. Current Mississippi River LWRP stages (feet).

Station	Existing LWRP
St. Louis	-3.5
Chester	-0.6
Thebes	4.8
Cairo	9.9
Memphis	-6.7
Helena	-2.2
Arkansas City	-1.1
Vicksburg	2.4
Natchez	7.3
Red River Landing	12.3

To assess the impact of the alternatives on the Mississippi River LWRP, the original LWRP computation procedure was modified to produce reasonable estimates of the impacts on the Mississippi River LWRP resulting from the change in the Missouri River flow. The current analysis consisted of four steps, as described below.

1. Compute the 97 percent exceedance flow at each of the 10 Mississippi River discharge gaging stations listed in Table 7.15-4 for the CWCP, the MCP, and the four GP options using the 1954 to 1991 period of record. Table 7.15-5 contains the 97 percent exceedance flows at each gaging station for each alternative computed from model-routed flows.
2. Use the 1988 (low-water year) observed discharge measurements to develop low-water rating curves at each of the 10 gaging stations by drawing a best-fit curve through measured points. Then raise or lower the curve to match the point defined by the existing LWRP stage and the 97 percent exceedance discharge from the CWCP, which represents the base plan. The use of the single rating curve (1988) deviates from the actual method used in computing the LWRP. The actual method involves developing a set of 10 rating curves (one for each year from 1982 through 1991), converting the 97 percent exceedance flow to stages, and then taking the average of the 10 stages to determine the LWRP. A single rating curve was used in this study for the sake of expediency.
3. Draw a line tangent to each of the rating curves at a point defined by the existing LWRP stage and the 97 percent exceedance discharge from the CWCP. This tangent line defines the slope of the curve at the LWRP stage. The slopes, shown below, were rounded off and grouped by Corps District reaches for simplicity and consistency of results:

   St. Louis District 5.5 kcfs/foot
   (St. Louis, Chester, Thebes)

   Memphis District 13.0 kcfs/foot
   (Hickman, Memphis, Helena)

   Vicksburg District 14.0 kcfs/foot
   (Arkansas City, Vicksburg, Natchez)

   New Orleans District 18.0 kcfs/foot
   (Red River Landing)

4. Compute the impact on the LWRP by applying the slope to the difference in the 97 percent exceedance flows (between the CWCP and other alternatives). Table 7.15-6 shows the computed differences in the LWRP, with the positive values indicating the raising of the LWRP and the negative values indicating the lowering of the LWRP. Table 7.15-7 shows the adjusted LWRP stages.

Table 7.15-6 shows that all alternatives have negative impacts by lowering the LWRP, typically by 0.2 to 0.4 foot along the Middle Mississippi River and 0.2 to 0.3 foot along the Lower Mississippi River. The lowering of the LWRP will require the training dikes on the Mississippi River to be extended farther into the river at a substantial cost.

Table 7.15-5. 97 percent exceedance flow (kcfs).

Alternative	St. Louis	Chester	Thebes	Hickman	Memphis	Helena	Ark City	Vicksburg	Natchez	RRL
CWCP	56.4	59.2	60.1	138.9	147.7	151.2	170.0	176.7	173.9	130.0
MCP	54.4	56.8	57.7	136.7	146.0	149.2	167.3	172.8	170.3	127.8
GP2028	54.5	56.9	57.9	135.6	145.3	149.0	167.5	172.9	170.8	128.3
GP1521	55.5	58.2	59.2	135.0	144.6	147.7	167.1	172.9	172.4	128.3
GP2021	55.5	58.2	59.2	135.1	144.6	147.5	167.1	172.9	172.4	128.3
GP1528	54.8	57.2	58.3	135.6	145.3	149.0	167.5	172.9	170.8	128.3

Table 7.15-6. Change in Mississippi River LWRP relative to the CWCP (feet).

Alternative	St. Louis	Chester	Thebes	Hickman	Memphis	Helena	Ark City	Vicksburg	Natchez	RRL
CWCP	0	0	0	0	0	0	0	0	0	0
MCP	-0.35	-0.43	-0.44	-0.17	-0.13	-0.16	-0.19	-0.28	-0.25	-0.13
GP2028	-0.35	-0.41	-0.39	-0.26	-0.19	-0.17	-0.18	-0.27	-0.22	-0.09
GP1521	-0.17	-0.17	-0.16	-0.30	-0.25	-0.27	-0.20	-0.27	-0.11	-0.09
GP2021	-0.17	-0.17	-0.16	-0.29	-0.25	-0.29	-0.20	-0.27	-0.11	-0.09
GP1528	-0.29	-0.35	-0.34	-0.26	-0.19	-0.17	-0.18	-0.27	-0.22	-0.09

Table 7.15-7. Revised Mississippi River LWRP (feet).

Alternative	St. Louis	Chester	Thebes	Hickman	Memphis	Helena	Ark City	Vicksburg	Natchez	RRL
CWCP	-3.50	-0.60	4.80	9.90	-6.70	-2.20	-1.10	2.40	7.30	12.30
MCP	-3.85	-1.03	4.36	9.73	-6.83	-2.36	-1.29	2.12	7.05	12.18
GP2028	-3.85	-1.01	4.41	9.64	-6.89	-2.37	-1.28	2.13	7.08	12.21
GP1521	-3.67	-0.77	4.64	9.60	-6.95	-2.47	-1.30	2.13	7.19	12.21
GP2021	-3.67	-0.77	4.64	9.61	-6.95	-2.49	-1.30	2.13	7.19	12.21
GP1528	-3.79	-0.95	4.46	9.64	-6.89	-2.37	-1.28	2.13	7.08	12.21

Table 7.15-8. Mississippi River channel improvement features cost by alternative.

Alternative	St. Louis LWRP (feet)	Change in LWRP (feet)	Increased Cost ($million)
CWCP	-3.50	0	0
MCP	-3.85	-0.35	17.5
GP2028	-3.85	-0.35	17.5
GP1521	-3.67	-0.17	8.5
GP2021	-3.67	-0.17	8.5
GP1528	-3.79	-0.29	14.5

Table 7.15-8 presents the cost associated with Mississippi River channel improvement feature modifications resulting from the respective alternatives. A previous study by the St. Louis District determined that, for each 0.1 foot of reduction in the existing LWRP, the cost of new construction of training structures for the Middle and Lower Mississippi River reaches would be $5 million. This cost is associated with maintaining a 9-foot navigation channel in the Mississippi River. This does not include environmental impacts that may accrue from changing channel improvement features.

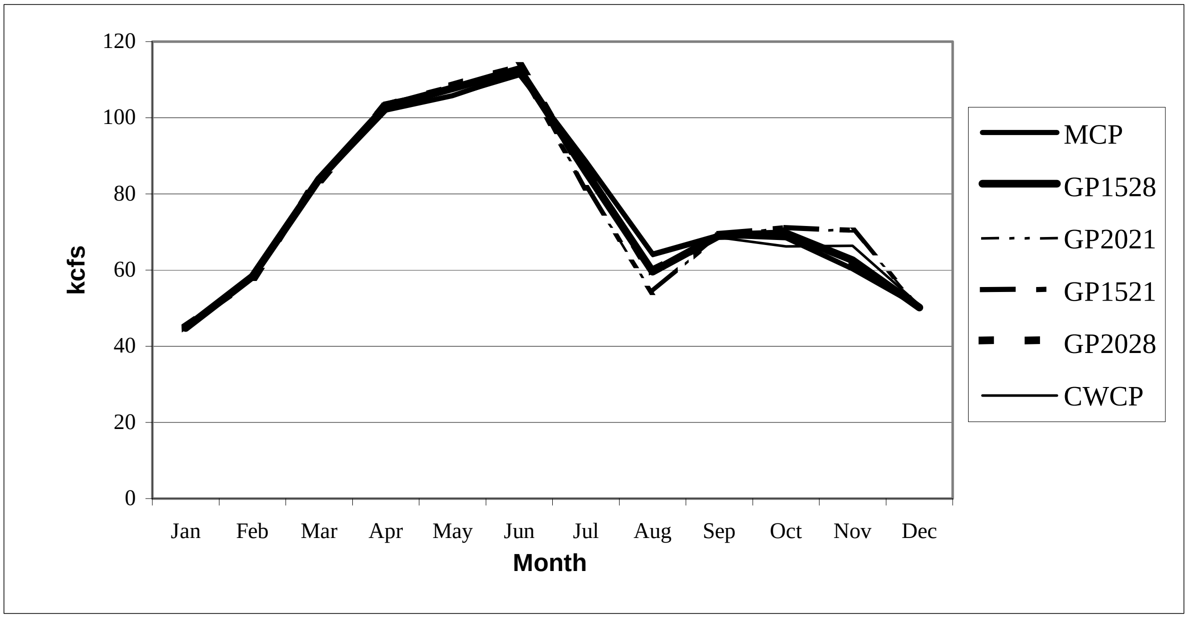


Figure 7.15-1. Average monthly flow at Hermann, Missouri.

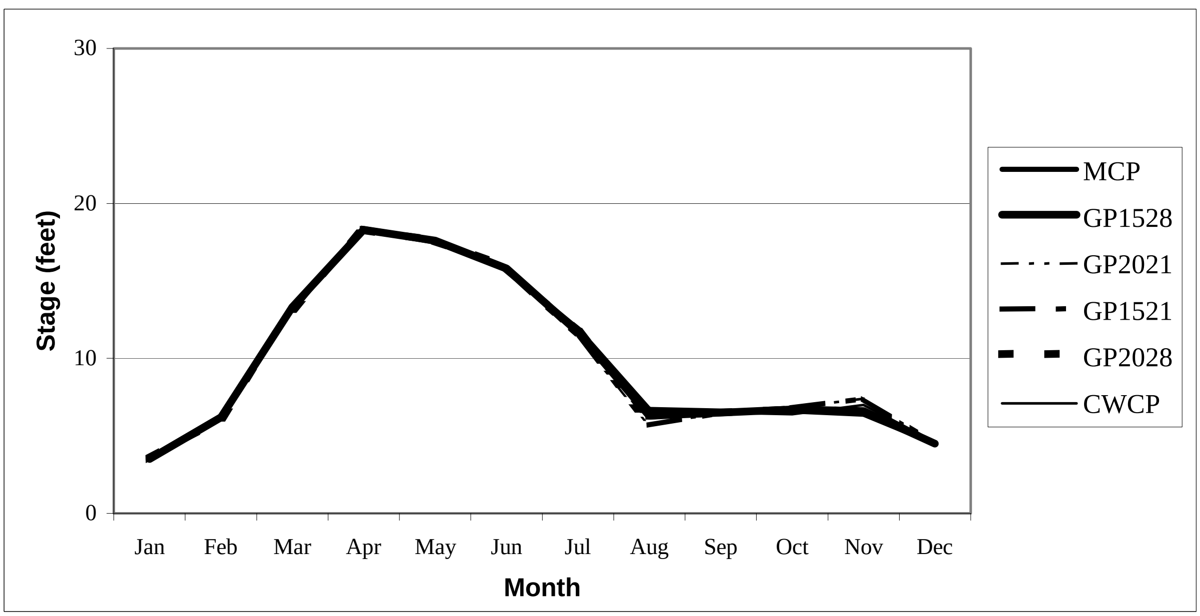


Figure 7.15-2. Mean monthly stage at St. Louis.

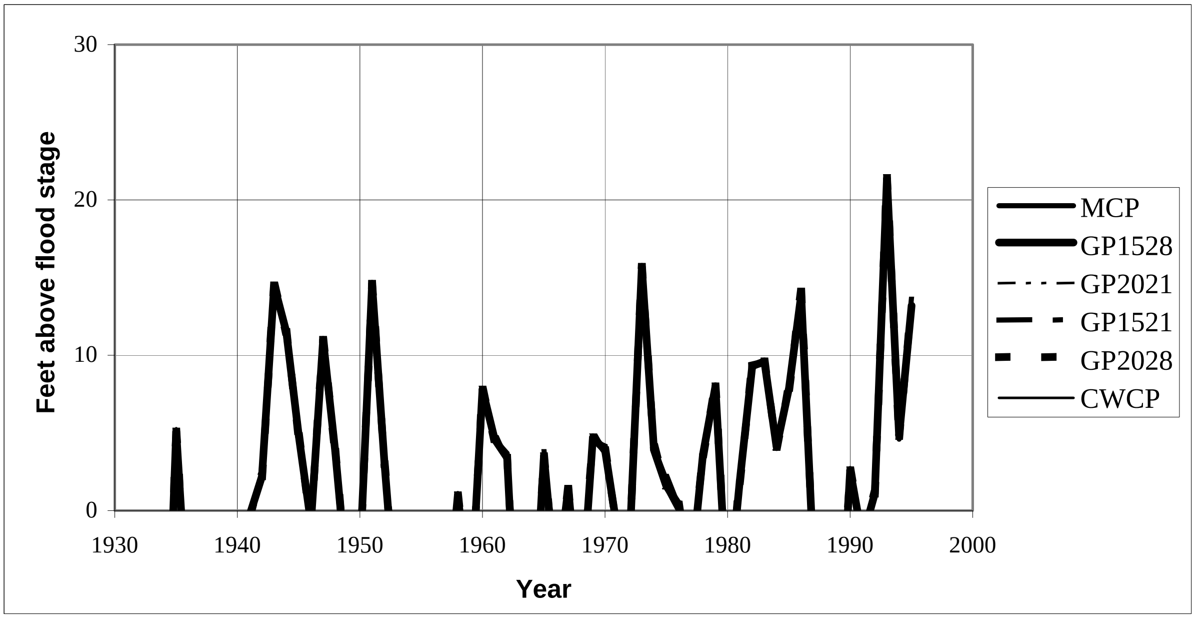


Figure 7.15-3. Maximum annual stage at St. Louis.

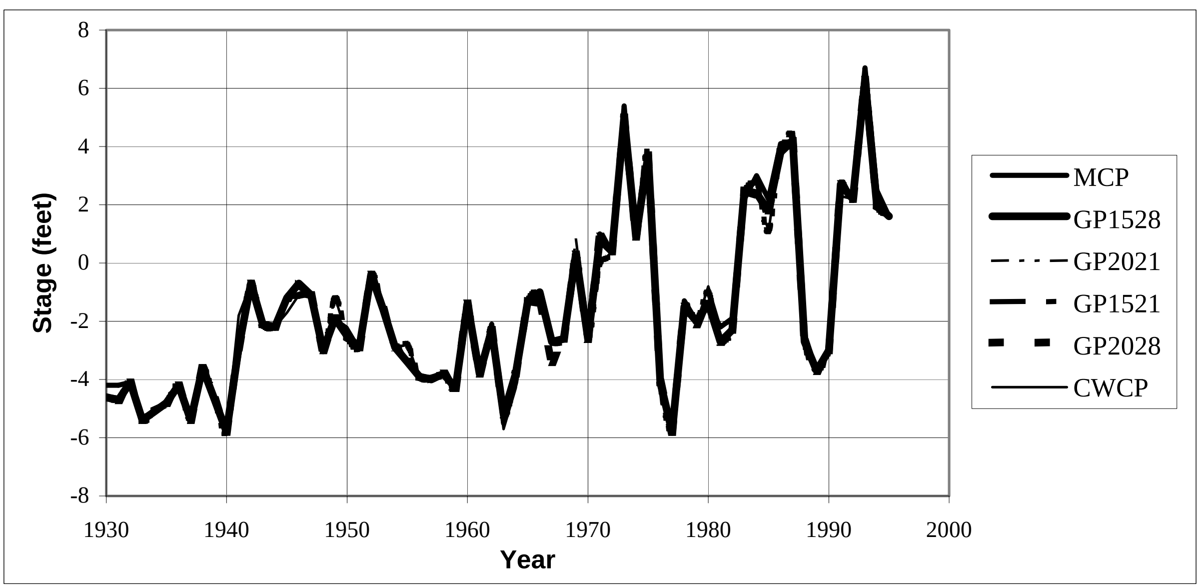


Figure 7.15-4. Minimum annual stage at St. Louis.

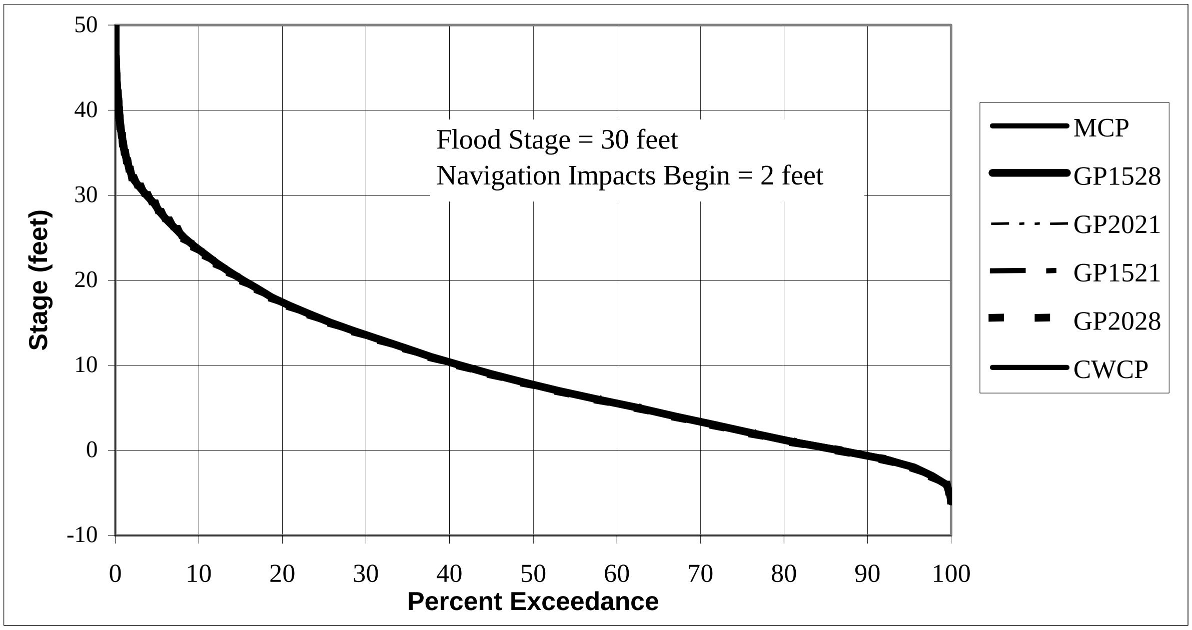


Figure 7.15-5. Average annual St. Louis stage duration.

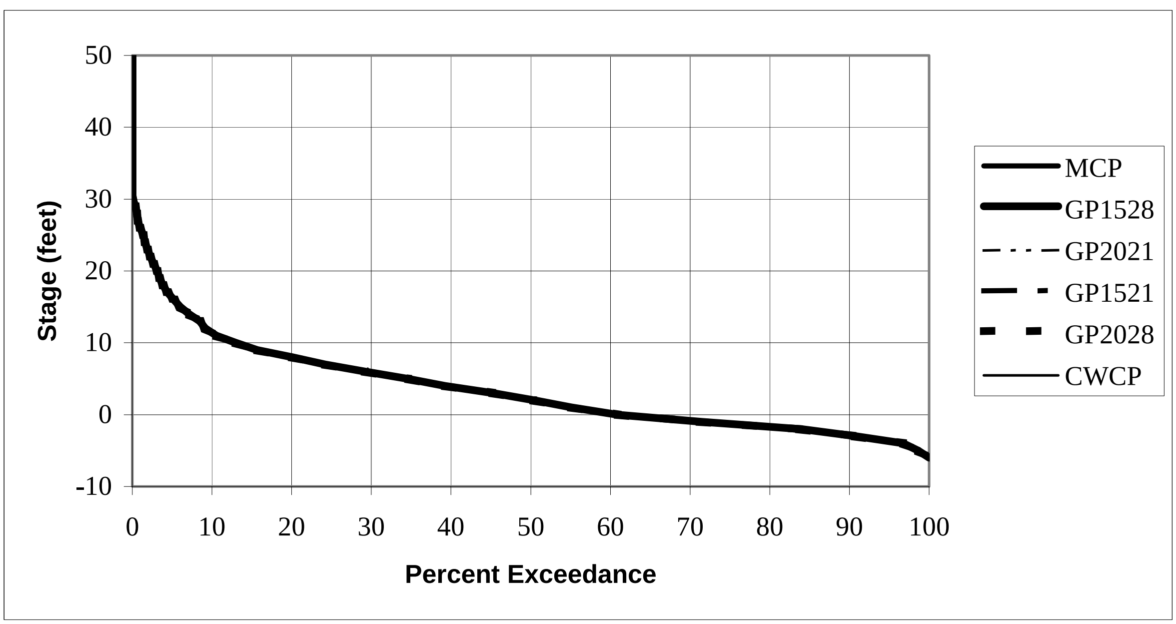


Figure 7.15-6. St. Louis stage duration, January.

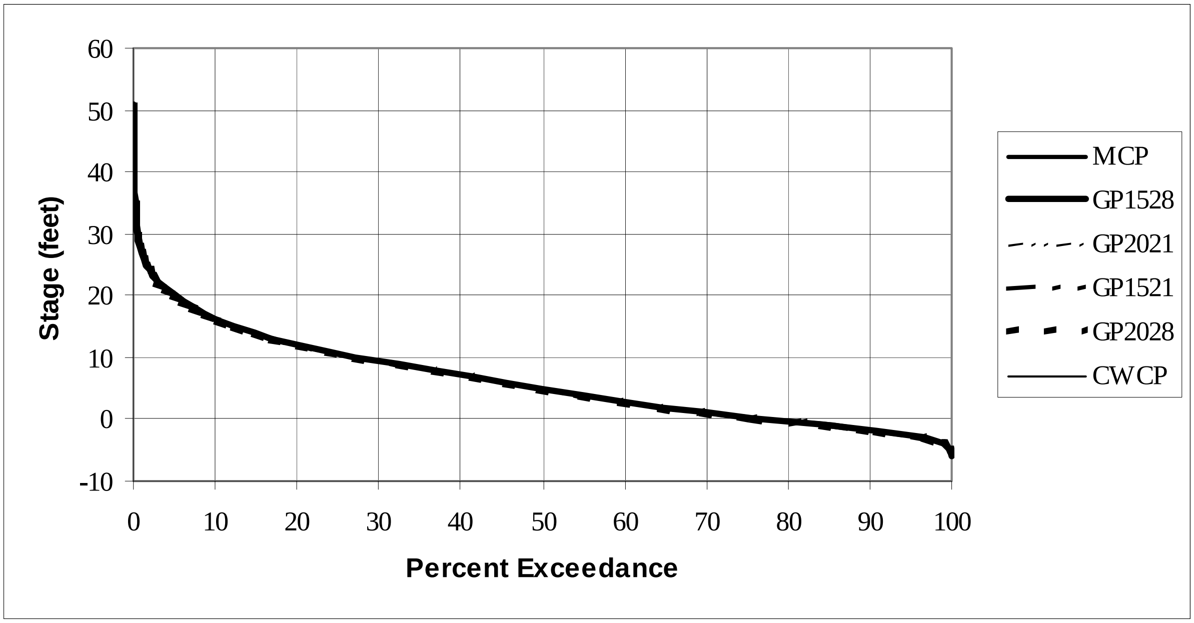


Figure 7.15-7. St. Louis stage duration, February.

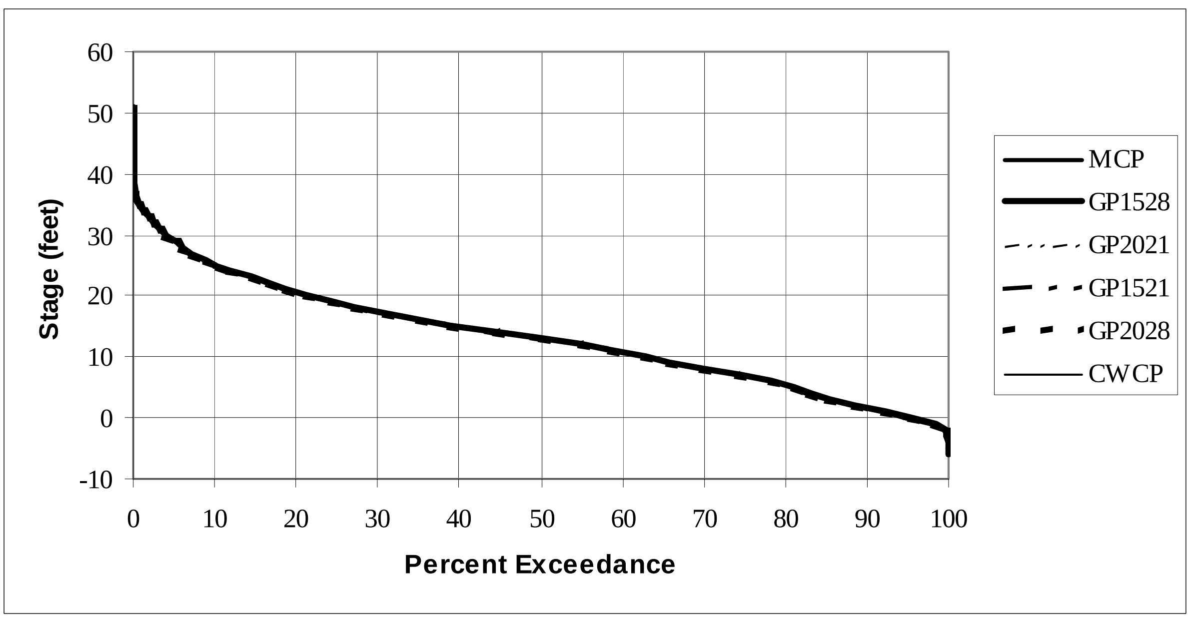


Figure 7.15-8. St. Louis stage duration, March.

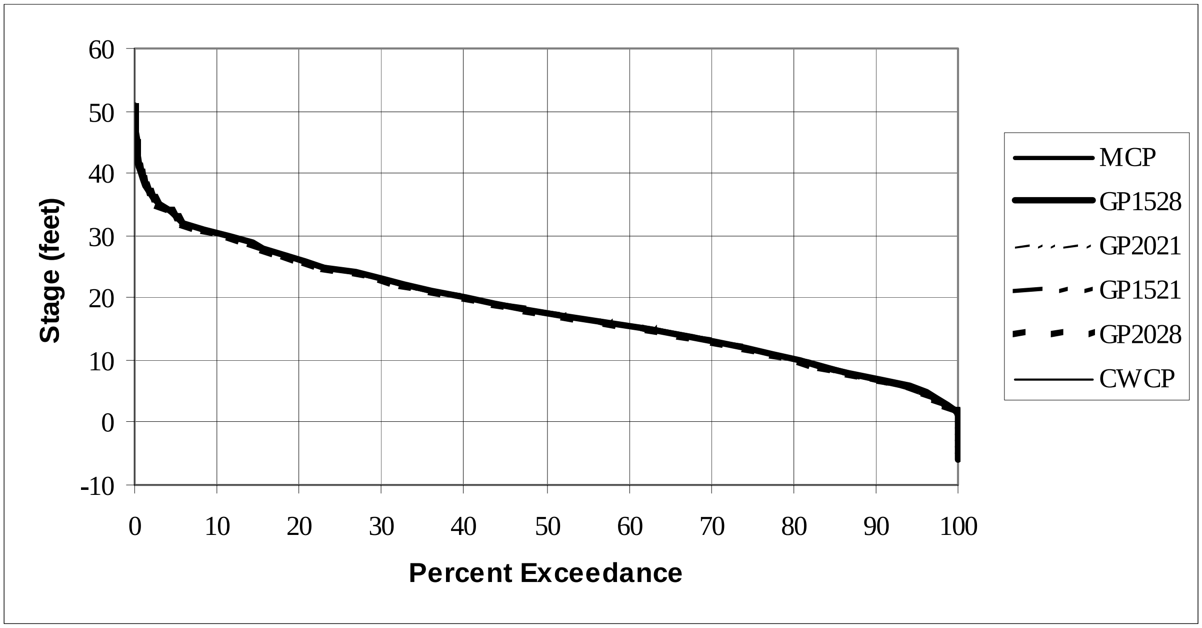


Figure 7.15-9. St. Louis stage duration, April.

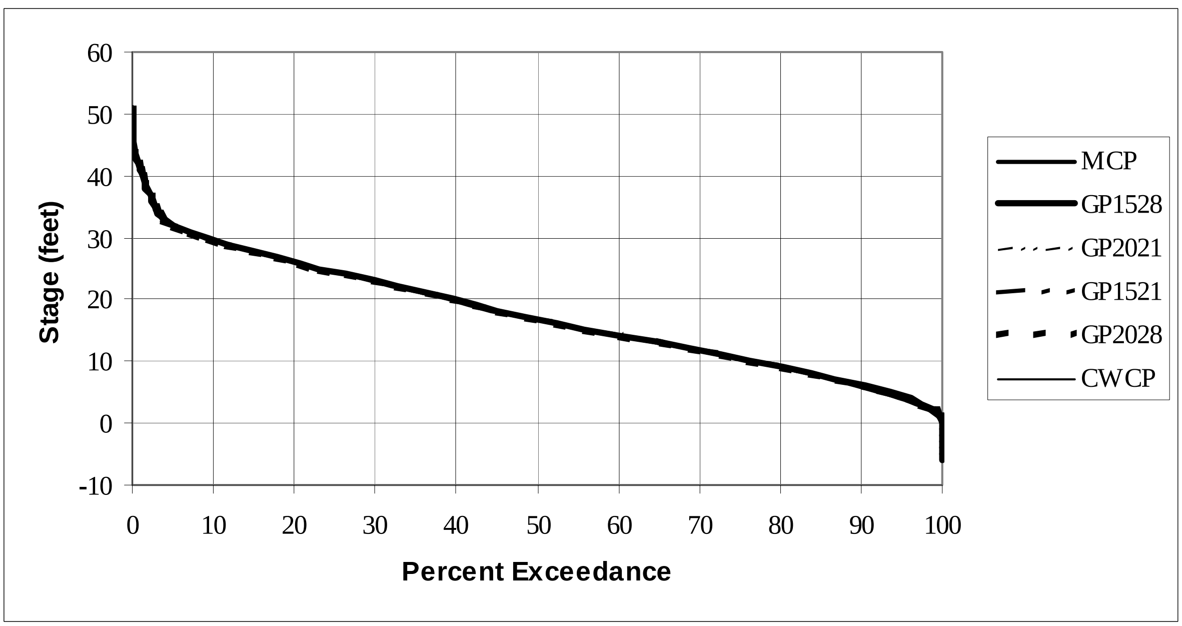


Figure 7.15-10. St. Louis stage duration, May.

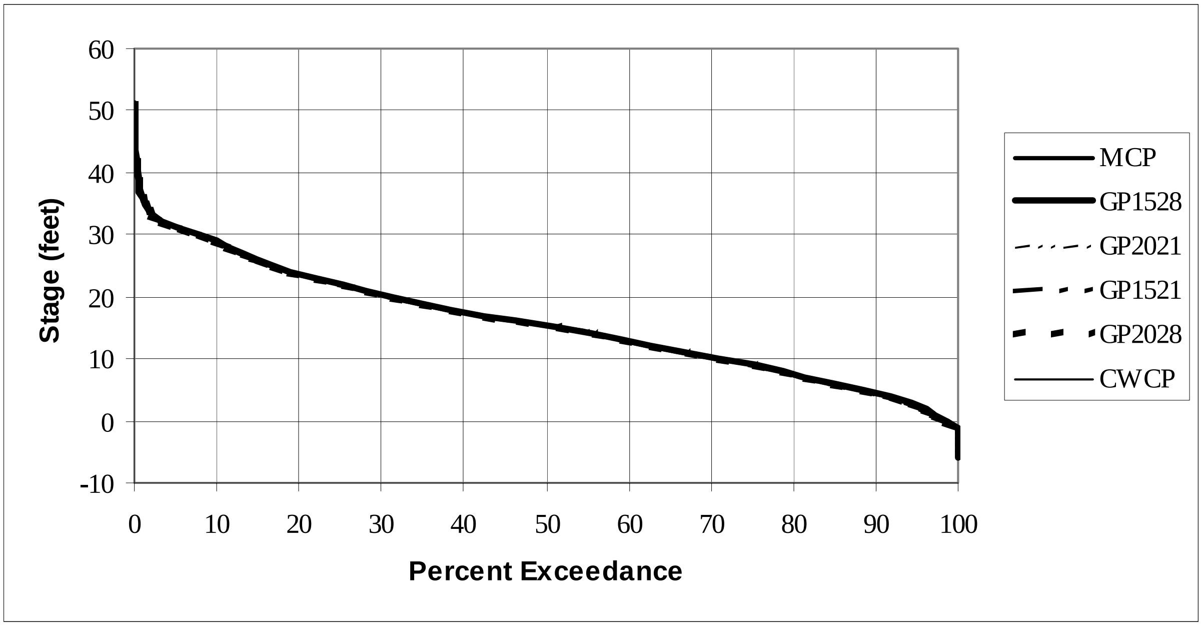


Figure 7.15-11. St. Louis Stage Duration, June.

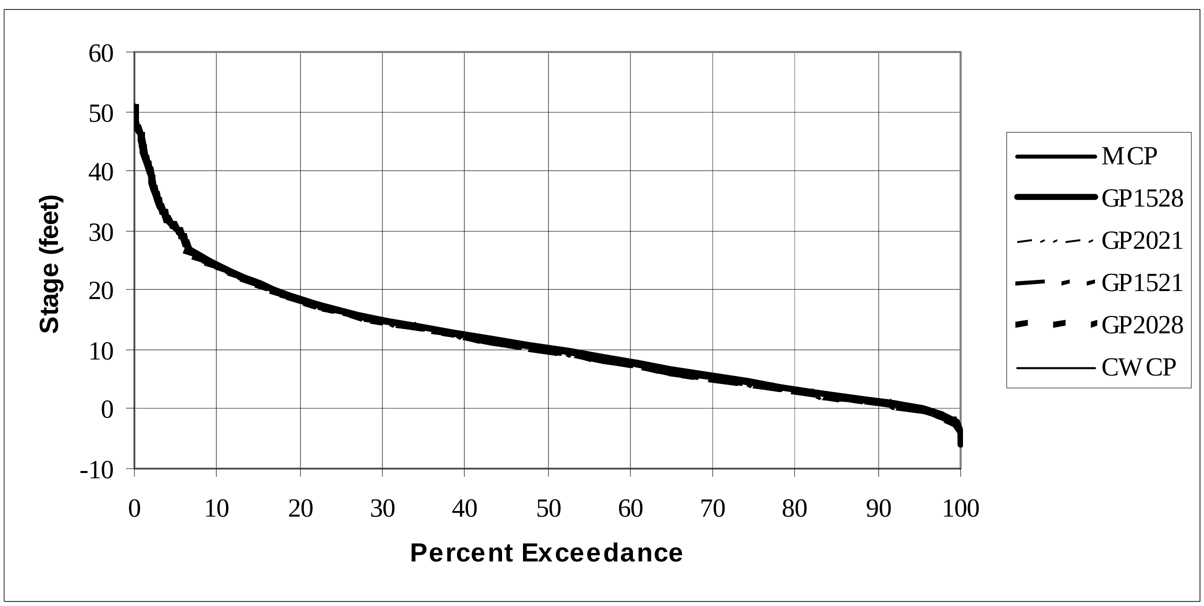


Figure 7.15-12. St. Louis stage duration, July.

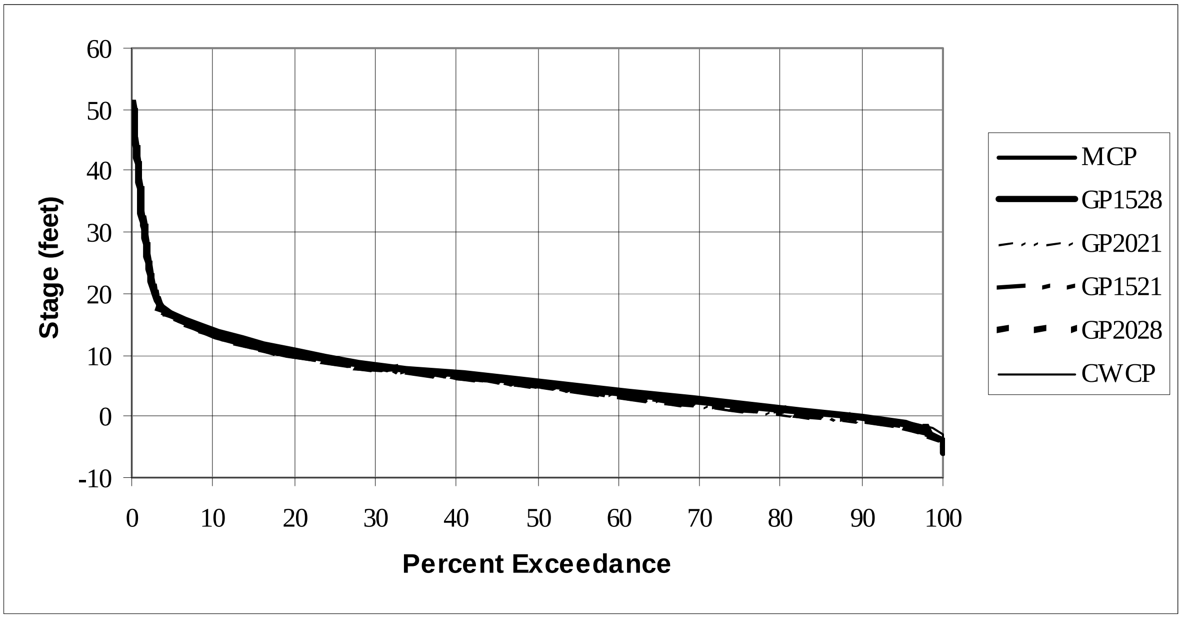


Figure 7.15-13. St. Louis stage duration, August.

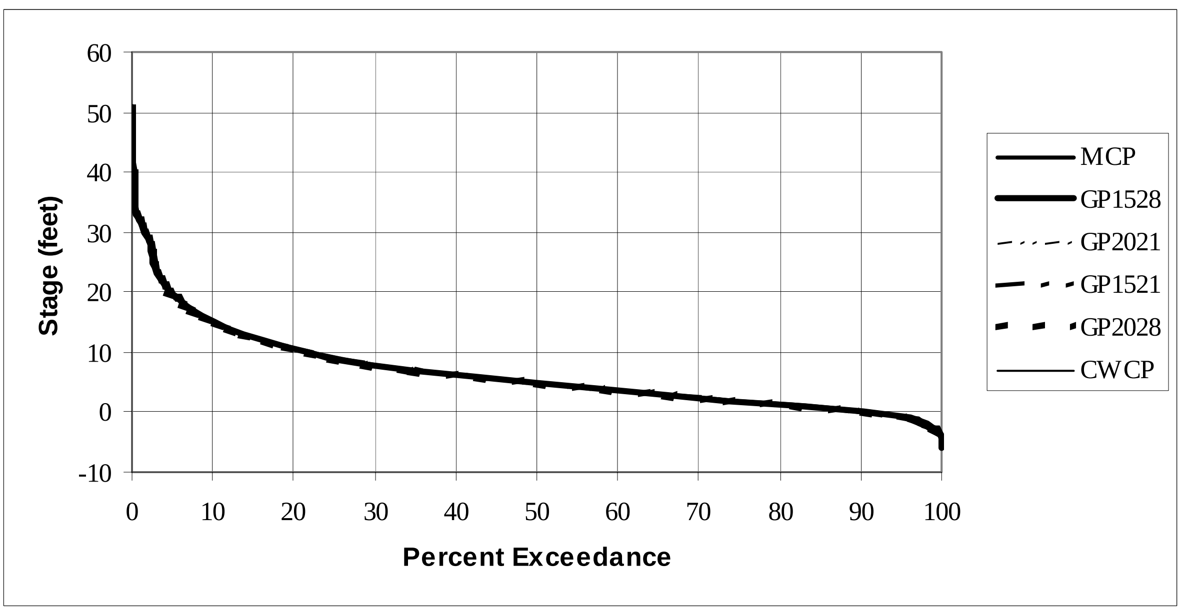


Figure 7.15-14. St. Louis stage duration, September.

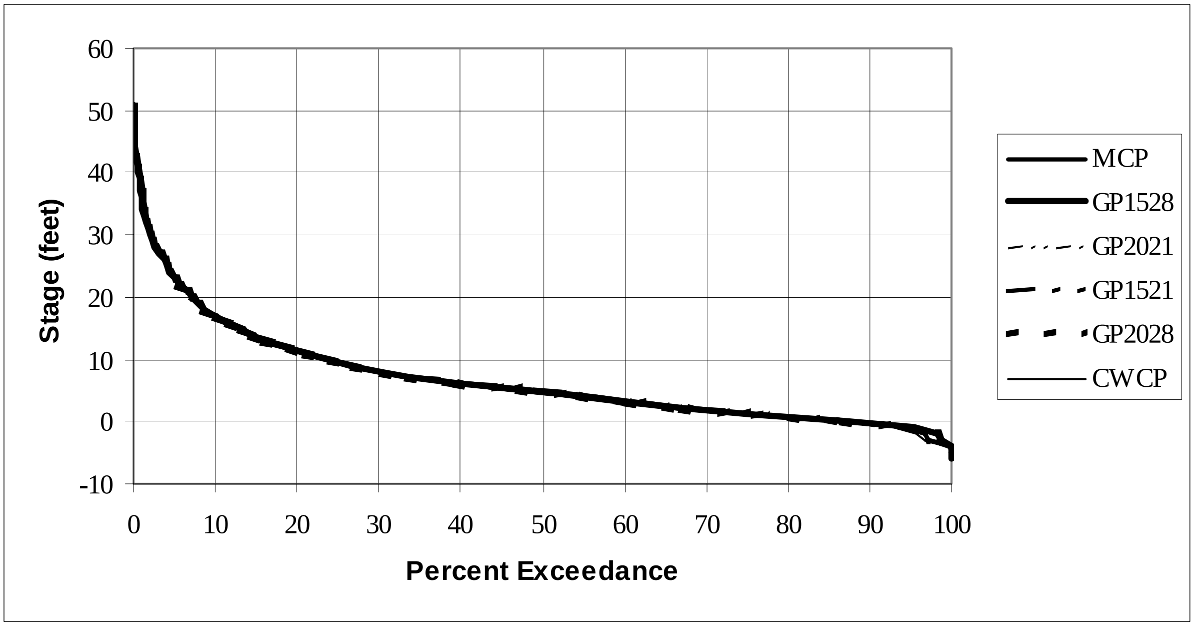


Figure 7.15-15. St. Louis stage duration, October.

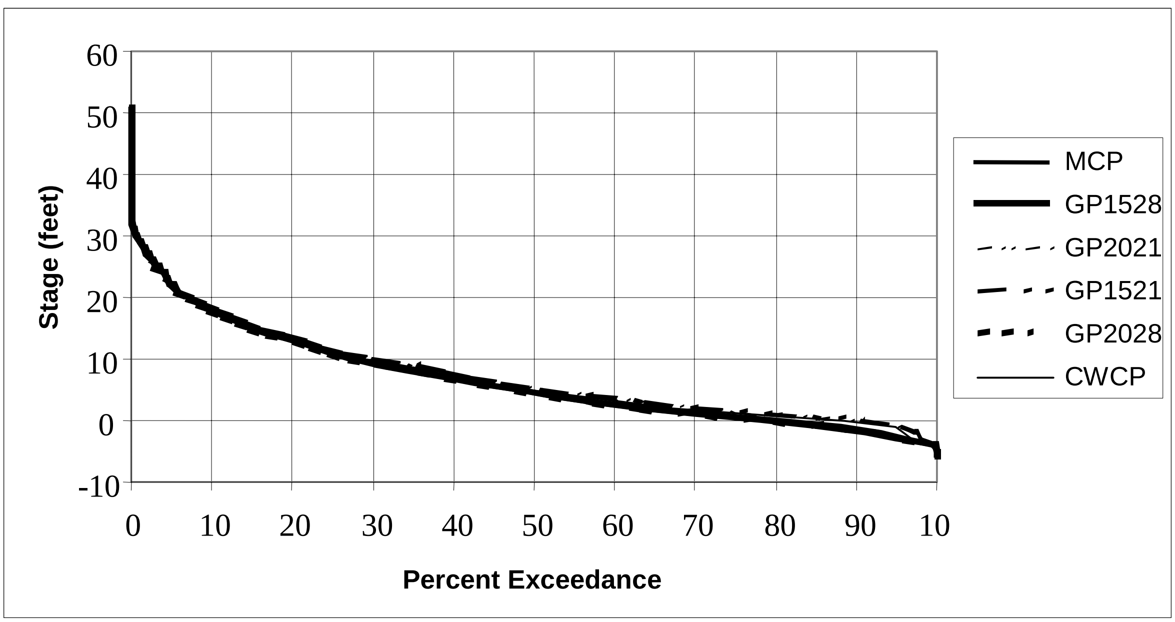


Figure 7.15-16. St. Louis stage duration, November.

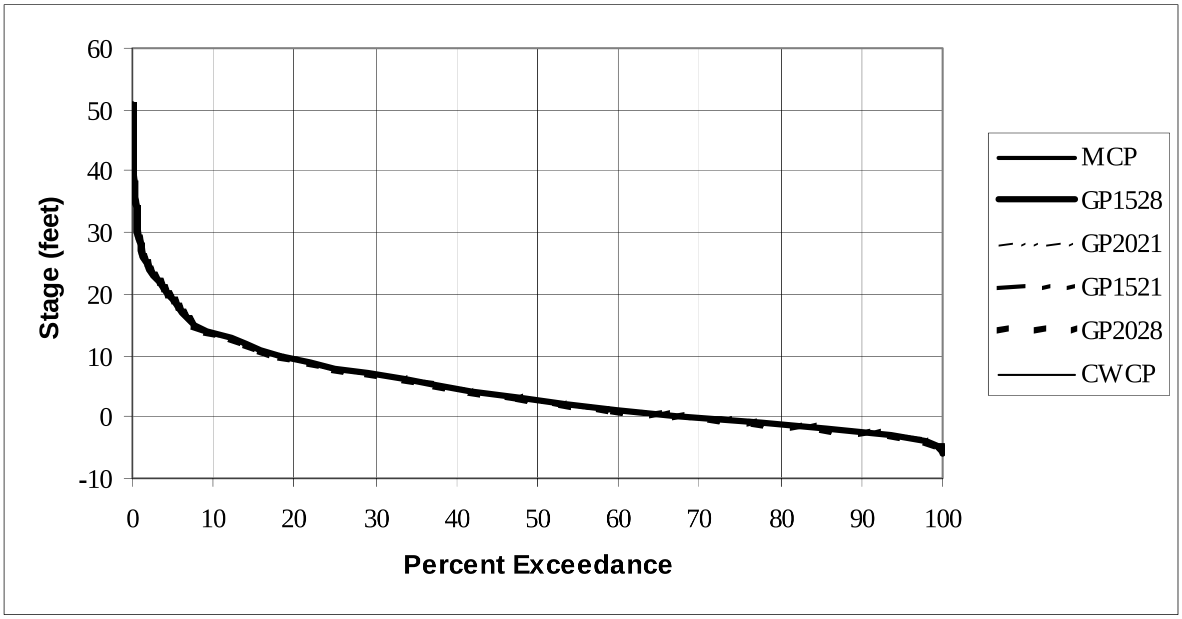


Figure 7.15-17. St. Louis stage duration, December.

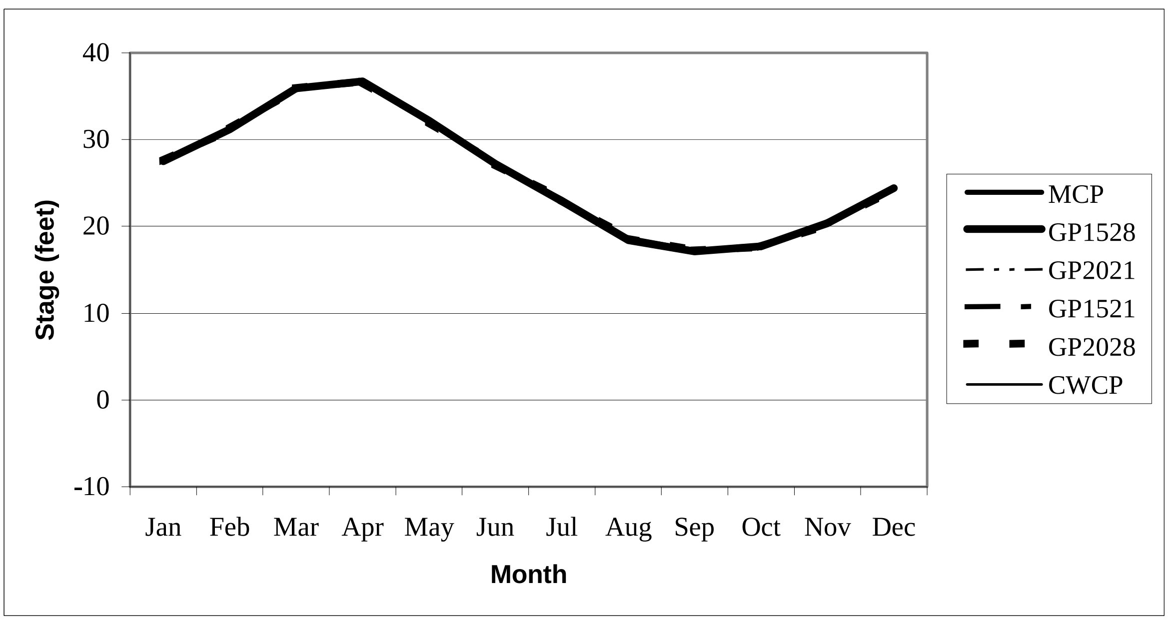


Figure 7.15-18. Mean monthly stage at Cairo.

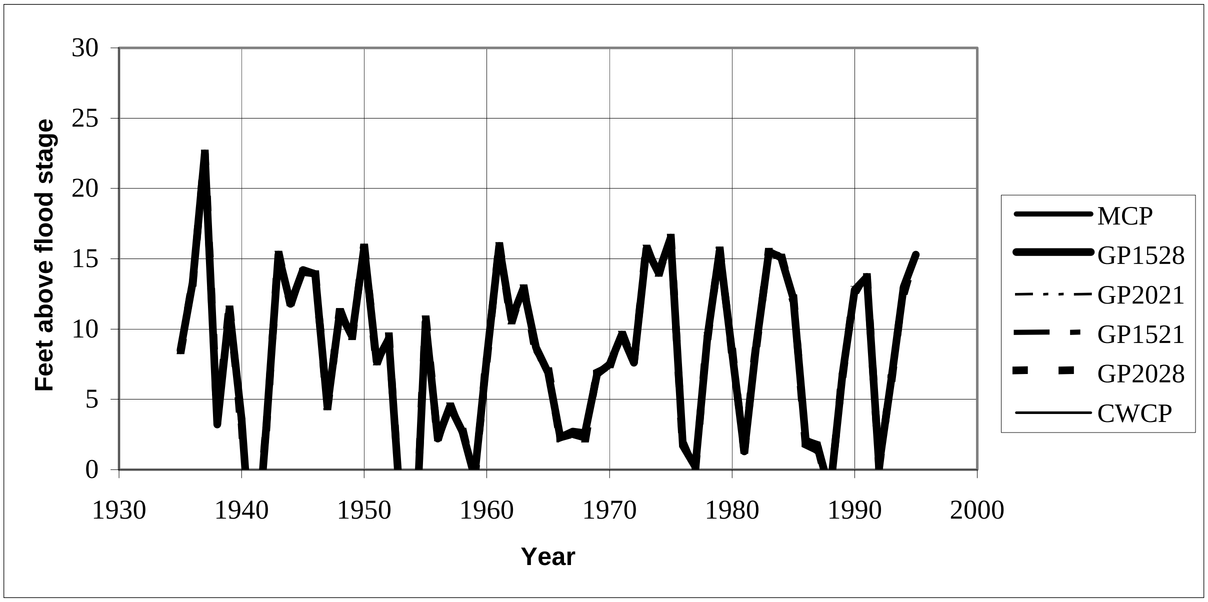


Figure 7.15-19. Maximum annual stage at Cairo.

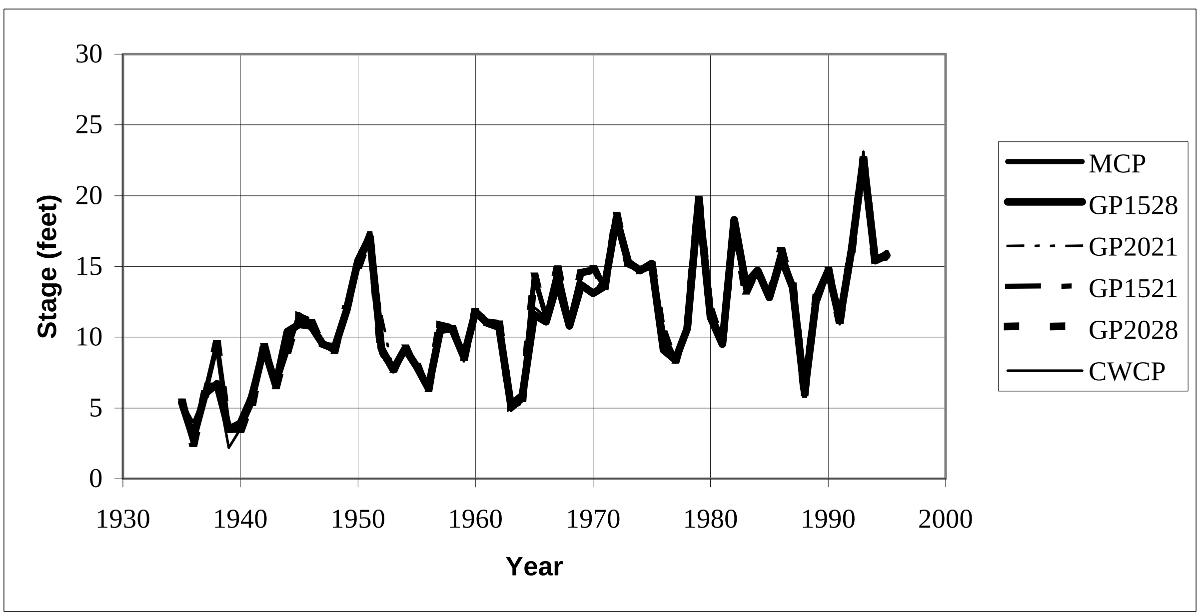


Figure 7.15-20. Minimum annual stage at Cairo.

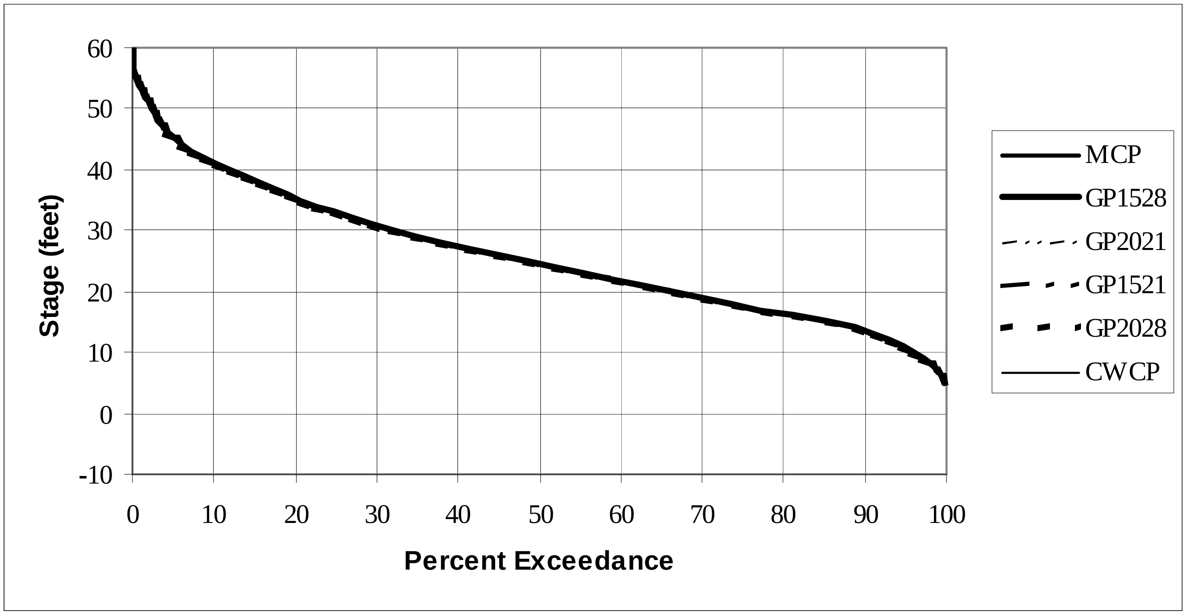
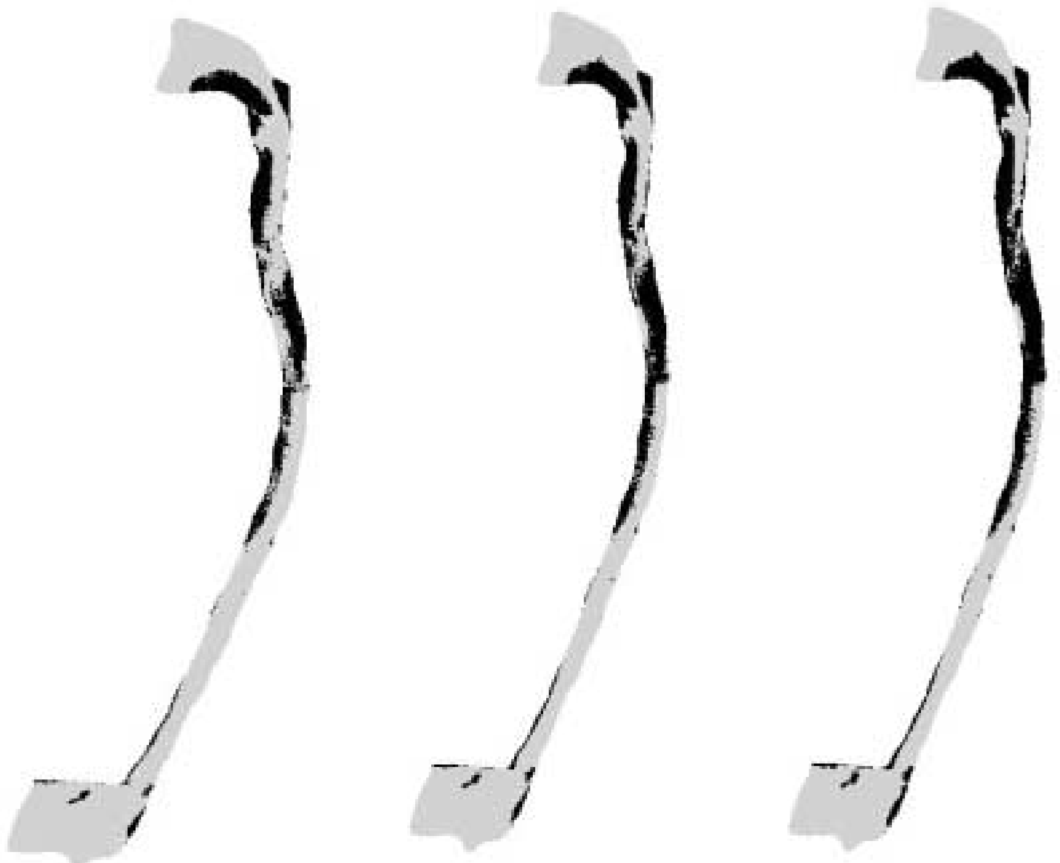


Figure 7.15-21. Cairo stage duration.

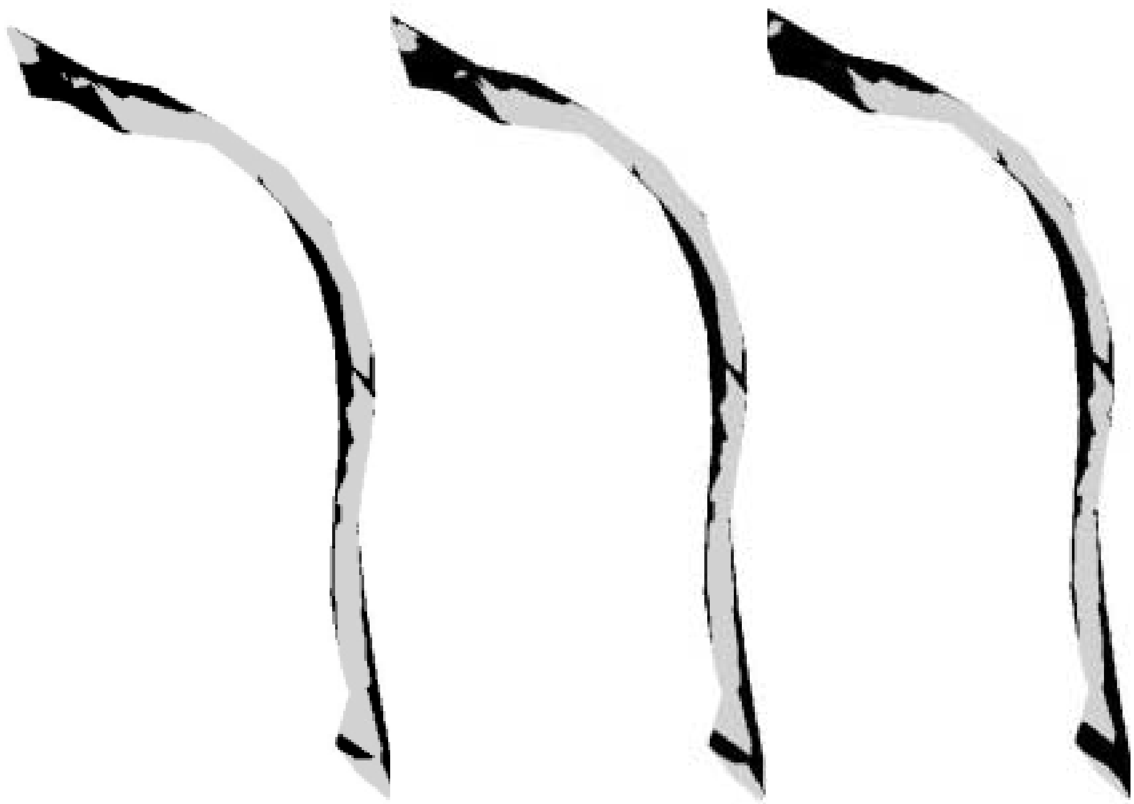
Figure 7.15-22. Example of Jefferson Barracks Chute during average low river stages in August.



CWCP **GP1528** **GP2021**

Note: Gray indicates aquatic areas, while black indicates dry areas. The figure shows that there is some flow allowed through the chute in the CWCP, but under the GP1528 and GP2021 options, flow is cut off. North lies to the top of the page. The chute lies on the left descending bank of the Mississippi River, and connects at the top and the bottom of the page.

Figure 7.15-23. Example of Calico Chute during average river stages in August.

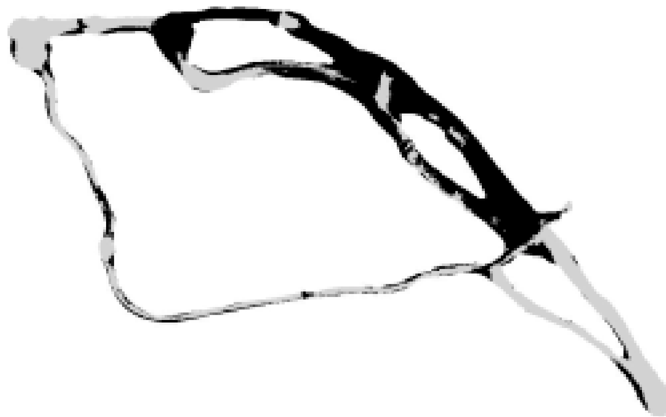


CWCP **GP1528** **GP2021**

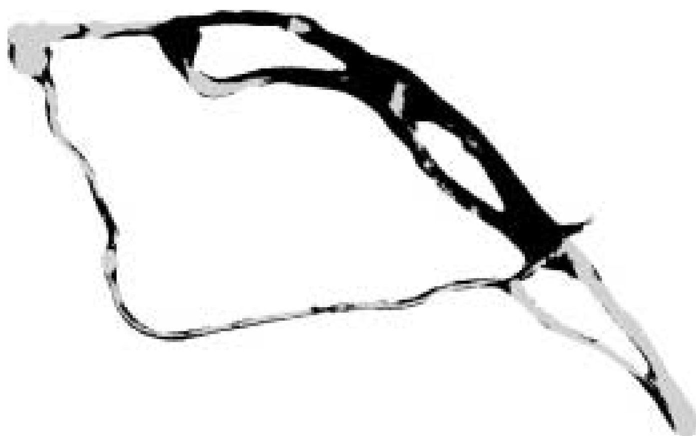
Note: Gray indicates aquatic areas, while black indicates dry areas. The figure shows that while there is no flow allowed through the chute in the CWCP, there is still a connection to the lower half of the chute. Under the GP1528 and GP2021 options, access is cut off. North lies to the top of the page. The chute lies on the left descending bank of the Mississippi and connects only at the top and bottom of the chute.

Figure 7.15-24. Example of Kasky Chute and island complex during average river stages in August.

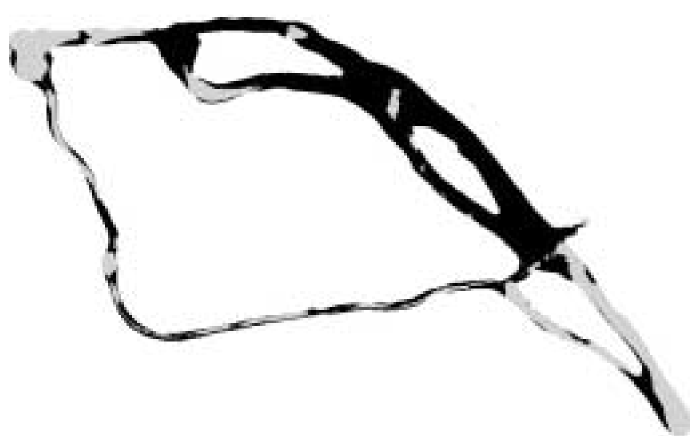
CWCP



GP1528



GP2021



Note: Gray indicates aquatic areas, black indicates dry areas, and no color represents upland. The figure shows that under the CWCP the southern most island is surrounded by connected water. Under the GP1528 plan access is cut off behind the island, and island tip habitat is lost under GP2021. North is to the top of the page, and the Mississippi River abuts directly adjacent to the north and east. The chute lies on the inside bend on the right descending bank of the Mississippi River.